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LESSONS LEARNED FROM THE DEVELOPMENT OF THE JOINT STAND-OFF TARGET ATTACK RADAR SYSTEM COMMON GROUND STATION

J. Daniel Sherman

This article examines eight major lessons learned from the development of the Joint Stand-off Target Attack Radar System (Joint STARS) Common Ground Station (CGS), beginning with systems development of the airborne moving target indicator radar and extending through development of the CGS. The Joint STARS program was an innovation in acquisition reform initiatives embedded in what was to become the Department of Defense 5000. However, in other respects Joint STARS was subject to programmatic difficulties and could have benefited from the acquisition principles of the 5000 series had it been implemented earlier. The identification of these lessons learned has important implications for the development of other systems.

An important problem historically encountered by ground commanders has been that much of the information regarding strength and location of enemy ground forces was unreliable, due to the limits of surface and airborne surveillance. Poor visibility due to weather and/or darkness and the inability to detect and locate moving vehicles over large areas were important limitations. Enemy forces could exploit these weaknesses by moving forces at night, in bad weather, or by moving forces so rapidly that surveillance lagged. It was clear that a system was needed to overcome these surveillance weaknesses—an airborne system that would give ground commanders

access to simultaneous, real-time information regarding enemy movements regardless of weather or darkness. Furthermore, the need existed for such an airborne sensor to provide information to help differentiate the locations of enemy versus friendly forces over a wide area.

Throughout the 1960s and 1970s, the Army and the Air Force pursued separate programs to address this problem. Army pursuits included Project PEEK (Periodically Elevated Electronic Kibitzer) using Moving Target Indicator (MTI) radar, the Mohawk Side-Looking Airborne Radar (SLAR), and the Stand-Off Target Acquisition System (SOTAS). Beginning in the 1970s, the Air Force pursued parallel development of a system based on moving target indicator radar technologies, the Multi-Lateration Radar Surveillance and Strike System (MLRS3), which led to the Multiple Antenna Surveillance radar (MASR) and then the Pave Mover program.

JOINT STARS: THE MERGING OF THE ARMY SOTAS AND AIR FORCE PAVE MOVER PROGRAMS

By 1982, it was apparent to both the House Armed Services Committee and the Office of the Secretary of Defense that two separate programs (Army and Air Force) with significant overlapping requirements were not cost effective. In May 1982, the Joint STARS program office was established at the Electronic Systems Division at Hanscom Air Force Base, Massachusetts. The mission would be to develop a single multi-mode target acquisition and attack system. Initially, the Army was a reluctant partner, but had no other alternative to the joint program to meet their Ground Moving Target Indicator (GMTI) requirement. So discussions were initiated that would determine the division of labor between the Army and the Air Force, and early on, it was determined that the Air Force would assume responsibility for the platform (aircraft). Developments from the Pave Mover program and the work of the Grumman (now Northrop Grumman) and Hughes Corporations demonstrated how a common radar could be developed to meet the Air Force requirement for a synthetic aperture radar (SAR) and the Army requirement for a moving target indicator (GMTI). Because of the advances that had been made by the Army on the SOTAS ground station, it was determined that the Army would assume full responsibility for the ground station program, including the data link.

During the same timeframe, it was determined that because of its technological maturity the design characteristics of the preceding SOTAS ground station would be adopted for the Joint STARS Ground Station Module (GSM). This decision resulted in significant cost savings and schedule reduction. Thus, in August 1984, Motorola was awarded the full-scale engineering development contract for the GSM. During this same year, the Army Joint STARS GSM project office transitioned from the U.S. Army Electronics Research and Development Command (ERADCOM), which later became the Army Research Laboratories, to the Communications and Electronics Command (CECOM), in Fort Monmouth, New Jersey. The project office would also be supported intensively by the Electronic Warfare Reconnaissance, Surveillance, and Target Acquisition Directorate (EW/RSTA).

In July 1985, the Grumman Corporation was selected as prime contractor for full-scale development. Their primary responsibilities included systems integration, signal processing, and the conversion of the Boeing 707 aircraft. Norden Systems was selected as the subcontractor for the SAR and GMTI radar. The Harris Corporation was selected to be the subcontractor to Motorola on the communications data links. Other major subcontractors included MITRE for technical monitoring and systems integration, Telephonics for some of the on-board electronics, Rolm Mil-Spec Computer Company for the computer disk storage, Control Data Corporation for programmable signal processors, and Magnavox for the Ultra High Frequency (UHF) communications system (Robert Guarino, personal communication, March 27, 2002).

THE JOINT STARS SYSTEM CHARACTERISTICS AND CAPABILITIES

The capabilities of the Joint STARS system would include the ability to locate and track moving ground vehicles, as well as being able to distinguish between tracked and non-tracked vehicles. The system would operate day or night and in most weather conditions, while the SAR and GMTI radar would be capable of operating in an electronic counter measures (ECM) environment. The Boeing 707 (E8A) aircraft would have mid-air refueling capability and could remain in its orbiting pattern for up to 20 hours.

The capabilities of the Joint STARS system would include the ability to locate and track moving ground vehicles, as well as being able to distinguish between tracked and non-tracked vehicles.

The system would be capable of conducting ground surveillance to develop an understanding of the enemy's location and to support attack operations and targeting that would contribute to the delay, disruption, and destruction of enemy forces. While flying in friendly airspace, the system would be able to look deep behind enemy lines to detect and track ground movements in both forward and rear areas. The system would have a range of 250 kilometers with a 120 degree field of view, thus covering nearly 50,000 square kilometers. These capabilities would be useful not only during actual combat, but in assessing impending military aggression, international treaty verification, and possible border violations.

The radar data would be transmitted via the secure data link to the GSM, which would be disseminated to the following echelons: above corps, corps, corps artillery,

division, and division artillery. This capability to distribute near real-time intelligence concerning both moving and fixed targets would provide a critical advantage to Army forces. The radar would have the capability of performing sector searches inside a wide-area field of view in either high- or medium-resolution search modes, providing synthetic aperture radar, fixed target indication imagery, and smaller area GMTI display (Marshall Greenspan, personal communication, March 14, 2002).

The use of the Joint STARS prototype system in the Gulf War exceeded all expectations, and engineering development continued in the aftermath.

The turning point for the Joint STARS program came in August 1990, when Iraqi forces invaded Kuwait. Although the production systems were not scheduled to be deployed until 1997, in September 1990, the two prototype Joint STARS systems were sent to Europe to participate in Operation Deep Strike as an operational test. The Deep Strike exercises simulated a large "Soviet" ground force attack against NATO forces. At one critical point in the exercises, Lieutenant General Frederick Franks, commander of Army VII Corps, used the data disseminated from the Joint STARS ground station to identify and counterattack a "Soviet" armor column, played by a Canadian tank convoy. The engagement resulted in simulated destruction of over 50 tanks. General Franks and General John Galvin, Supreme Allied Commander Europe, became immediate converts and briefed General Norman Schwarzkopf on the results. By early December, following a Defense Science Board recommendation to deploy, a Joint STARS team traveled to Riyadh to discuss the feasibility of deploying the pre-production, development systems with General Schwarzkopf's staff. On December 17, 1990, the order came to move the prototype Joint STARS systems to Saudi Arabia for immediate service.

The use of the Joint STARS prototype system in the Gulf War exceeded all expectations, and engineering development continued in the aftermath. In May 1993, approval for the low-rate production of five Joint STARS E8C aircraft was granted. The first E8C was completed in December 1993 and made its first flight in March 1994. Additionally, approval was granted in 1993 for the low-rate production of 12 Medium GSMs. Prior to this decision, a limited user test of the Medium GSMs was successfully conducted. The Medium GSMs were subsequently fielded with contingency forces and used as training equipment.

In September 1994, the Army approved the low-rate production of 10 Light GSMs following the Force Development Test and Evaluation (FDT&E) conducted a month earlier. The Air Force Operational Test and Evaluation Center and the Army Operational Test and Evaluation Command conducted a combined development and operational test of the system from July through September, 1995, and an operational

evaluation of the system during its deployment in Operation Joint Endeavor in Bosnia from December 1995 through March 1996. Initially, one of the E8As and the first production E8C were deployed with 13 GSMs and successfully flew 95 consecutive operational sorties and more than 1,000 flight hours. The two Joint STARS aircraft and the associated GSMs were deployed again in Bosnia in October 1996 with the addition of the second production E8C in December 1996. In 1996, the Under Secretary of Defense for Acquisition and Technology approved the Joint STARS program's entry into full-rate production. However, performance during its combined development and operational test, and the operational evaluation done in Bosnia, did not support a decision to commit to full-rate production.

It was not until August 2000 that full-rate production was finally approved. In October 2001, Motorola sold its defense business unit that was responsible for the development and production of the Joint STARS ground station to General Dynamics. Then with the Iraq War erupting in 2003, Joint STARS was utilized extensively. On March 27, 2003, under the cover of a sandstorm, a large Iraqi column attempted to attack the 3rd Infantry Division 80 miles south of Baghdad. In a widely publicized success, Joint STARS detected the Iraqi movement and called in air strikes that decimated the Iraqi column just miles from the lead elements of the 3rd Infantry Division.

LESSON 1: EARLY DEPLOYMENT IN A CRISIS CAN BE AN IMPORTANT OPERATIONAL TEST

In retrospect, looking back from the Iraq War (Operation Iraqi Freedom) to the first Gulf War (Operation Desert Storm), the decision to deploy the engineering development Joint STARS GSMs and E8As in 1991, almost six years prior to planned initial operational capability, was a bold decision and a calculated risk. However, the conservative decision to not deploy would have resulted in the loss of an opportunity for an important operational test. It would have also resulted in the loss of an opportunity to prove the system's capabilities and gain valuable support for the program's future funding (Jay Loomis, personal communication, March 12, 2002).

A great deal was learned from the sorties during the first Gulf War. The GSM dissemination of information to Army commanders had been slower than required. In addition, with 16 radios operating simultaneously during full utilization, there were delays due to frequency management. This vital experience resulted in subsequent improvements in the utilization of GSM-transmitted data. The critical need for more consoles for both Air Force and Army personnel on the E8 was also found during the Gulf War experience. Retired MITRE executive Charles Fowler observed that most of the early radars deployed during World War II were developmental. Incremental improvements were made as a result of operational experience. He noted that the potential value of testing the prototype system under conditions of combat should not be underestimated (Charles Fowler, personal communication, March 18, 2002). The first Gulf War experience with Joint STARS illustrated this lesson.

LESSON 2: THE GULF WAR PERFORMANCE OF THE GSM WAS MADE POSSIBLE BY THE LEVEL OF TECHNOLOGICAL MATURITY ACHIEVED BY THE START OF THE JOINT STARS PROGRAM

It is likely that the GSMs would have never been ready for deployment in the Gulf War if a high level of technological readiness had not been achieved by the start of the Joint STARS program in 1984. For example, Bill Gebele of the government Joint STARS GSM project office observed that by the time the SOTAS program was cancelled, the data link was completely developed (William Gebele, personal communication, March 18, 2002). With the launching of the Joint STARS GSM program the data link simply required incremental preplanned improvements. Allan Tarbell of the GSM project office observed that the time compression and time integration software that was pioneered during the SOTAS program was a central technology in the GSM (Allan Tarbell, personal communication, March 12/13, 2002). This work was largely accomplished in the 1970s and then incrementally improved with the software upgrades in the 1980s. This capability was central to the GSMs' operational effectiveness in the Gulf War.

Mr. Tarbell also noted that a major technological advance that had emerged from the commercial sector in the 1980s was the transition from stroker displays to raster scanning color monitors. This allowed for significantly greater resolution in the display of the radar data. The relative maturity of this technology allowed for a smooth transfer to the GSM display monitors. This had important implications for the interpretability of the data. Finally, the rate of advance in data processing speed was a major contributor to the GSMs' capability by the time of the Gulf War. The maturity of this technology could also be attributed to commercial advances in computing.

LESSON 3: A HIGH LEVEL OF COOPERATION FROM THE CECOM LABS CONTRIBUTED TO TECHNOLOGICAL READINESS

The government laboratories dating back to the SOTAS program, ECOM, and then ERADCOM provided a high level of support and played a major role in the development of the GSM. With the creation of the Program Executive Office (PEO) structure and the launching of the Joint STARS GSM project in the early 1980s, CECOM assumed a central role in supporting the program. Throughout its early development, ECOM, ERADCOM, and CECOM engineers moved into the project office as the program evolved. In fact, almost all of the early members of the project office came directly out of the laboratories. In addition, collocation of engineering personnel during the early years was used to facilitate the solution of a wide range of technical problems. While a number of the important technologies incorporated in the GSM came from the commercial sector, and some came from the contractors (e.g., time compression and time integration), the CECOM laboratories were involved in several critical areas. These included antenna design, materials decisions such as the use of carbon graphite in the antenna, signal processors, transmitters, simulation, testing, and other supporting tasks (Samuel Fusaro, personal communication, March 11, 2002).

LESSON 4: UNDERESTIMATING THE LEARNING CURVE

When Motorola was awarded the SOTAS contract in 1979 both the company and the government project office underestimated the learning curve for Motorola. This learning curve, however, had little to do with the technologies themselves. Both Allan Tarbell and Bill Kenneally indicated that Motorola had excellent technical depth in all the relevant technical areas (William Kenneally, personal communication, March 7, 2002). The company had extensive experience with most of the key technologies involved in the system. In addition, while Motorola was primarily a commercial firm, there were definite synergies with the program requirements in terms of technical core competencies. Thus, the difficulties were not related to integrating technology, but rather the learning curve was more programmatic in nature.

...the leap to becoming a systems integrator in a business (major defense systems) in which it [Motorola] had limited experience would prove to be more problematic than either the company or the government had anticipated.

Motorola had been a first-rate component supplier. However, the leap to becoming a systems integrator in a business (major defense systems) in which it had limited experience would prove to be more problematic than either the company or the government had anticipated. By the start of the SOTAS contract the company had not been validated for the CSCSC, the government's accounting system for major defense programs. Bill Kenneally and Allan Tarbell observed that while Motorola possessed the necessary technical capabilities, program management was not adept at managing defense projects and the cost overruns soon spiraled out of control. A major contributor to the cost overruns was the inaccurate cost estimating at the beginning that allowed for the bid that was $37 million below the government's own estimates. Finally, the failure to negotiate a reasonable price cap with the government for SOTAS engineering development led to the cancellation of the contract. Charles Fowler hypothesized that with greater managerial experience in the defense business, this event may have been avoided. To Motorola's credit, during the early years of the Joint STARS GSM program, the government electronics division was able to gradually make the necessary adjustments and improvements in program management.

LESSON 5: FIELD DEMONSTRATIONS TO GAIN TRADOC SUPPORT AND FUNDING STABILITY

An important element of the Army's air-land battle doctrine is the ability to command and control a fast moving, complex battlefield and to strike deep into enemy territory. This required the surveillance capability to look far behind enemy lines to accurately detect enemy forces and to bring weapons to bear against them. The requirement for this capability, however, did not necessarily mean that one particular approach would be adopted without the challenge of obtaining and maintaining TRADOC support.

While theoretically Joint STARS, and SOTAS before it, could vastly increase the Army's surveillance capability, the program needed to demonstrate the potential of the system to ensure necessary support. Beginning with SOTAS, and continuing through Joint STARS, the approach of using field demonstrations served two purposes. It allowed for useful testing, but also helped to build wide support for the program.

In 1990 the use of the two prototype Joint STARS systems in the Deep Strike exercises in Europe convinced General Franks and General Galvin that the system should be deployed in the Persian Gulf. Charles Fowler hypothesized that if the decision had been made to not send the system to the Gulf, subsequent funding in the 1990s may have been jeopardized. In contrast, the spectacular success of Joint STARS in the Gulf War virtually ensured funding stability for most of the decade of the 1990s.

LESSON 6: REQUIREMENTS INSTABILITY AND NON-ESSENTIAL REQUIREMENTS CAN RESULT IN AN UNDERESTIMATED ADVERSE IMPACT ON SCHEDULE

While the GSM program experienced relative funding stability, it suffered from a degree of requirements instability. Beginning with SOTAS, at the defense acquisition board review, a request was made that the system have an electronic scanning capability in addition to the mechanical scanning ability that had already been designed. Lt. General Cianciolo, the first SOTAS program manager, indicated that this requirement was not challenged in order to facilitate DoD approval. In retrospect, however, this turned out to be a mistake. The requirement was not actually essential, and neither Cianciolo, nor anyone in the government project office at the time, could have predicted that this requirement would become the major cost overrun and schedule problem in the SOTAS program.

Following the SOTAS cancellation and during the initial Joint STARS proposal timeframe, there was significant difficulty in reaching consensus on requirements. This resulted in a number of changes that prolonged the contract award schedule. This problem was even more profound on the Air Force side, resulting in significant delays. In 1986, in response to directives from the Army Vice Chief of Staff, the decision was made to design two versions of the GSM. These would include a Light GSM and a Medium GSM, known as the Block I Series. With this requirements change, the Interim Ground Station Module would never go into production and engineering

development work would progress on the Light and Medium GSMs. This, of course, had subsequent schedule implications.

In addition to requirements changes, the issue of non-critical requirements in terms of extraordinary nuclear, chemical, and biological survivability specifications contributed to further schedule delays. Charles Fowler observed that the inflexibility of the acquisition system prior to DoD 5000 (which enforces a uniform, standardized acquisition process) was also a major contributor to the schedule problems. The primary problem stemmed from the fact that the acquisition system essentially managed the acquisition of small-scale customized systems in a similar manner to systems with large-scale production runs.

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The problem of requirements changes creates a significant challenge for any program manager. This was no exception for Bill Kenneally and Bill Gebele of the Joint STARS GSM project office, and Irving Luke and Al Pavik of Motorola (Albert Pavik, personal communication, March 22, 2002). Clearly, what was needed was an operational requirements document that specified requirements at a high level of technology readiness and saved upgraded capabilities that involved less mature technologies for future preplanned product improvements. Currently, under DoD 5000, the preferred approach to systems development is evolutionary, based on a time-phased plan to develop a new system in incremental steps with reduced cycle times. This approach parallels best practices in commercial product development. Furthermore, it results in achieving performance objectives through a phased process whereby a graduated sequence of systems are fielded so that the warfighter does not wait a prolonged period of time for a single step to full capability.

Under DoD 5000 there are two basic approaches to evolutionary acquisition. The first process is incremental development. The desired capability is identified, end-state requirements are established, and systems development occurs in incremental blocks of preplanned product improvements with technology insertion based on technological maturity. The second basic process of evolutionary acquisition is generally referred to as spiral development. Here the end-state requirement is not known and each incremental upgrade of the system is based on direct feedback from the field. If either incremental development or spiral development had been employed as the acquisition strategy, the early history of Joint STARS may have been quite different. In any event, throughout

the 1990s, the program began to pioneer some of the basic tenets that emerged in DoD 5000.1 and 5000.2 in 2003 and 2004, respectively.

LESSON 7: DESIGN FLEXIBILITY AND OPEN ARCHITECTURE FOR A TECHNOLOGY INSERTION PROGRAM

Computer technology was advancing rapidly throughout the Joint STARS program, and as a consequence, changes in both hardware and software occurred as the program proceeded. During the 1980s the system utilized custom-designed militarized versions of commercial computers. This resulted in significant cost and schedule implications for each successive generation of upgrades.

Following the Gulf War in the early 1990s, significant changes in the form of open architecture and increased use of commercial off-the-shelf (COTS) technology resulted in reductions in cost and schedule for upgrading computer hardware and software. Similarly, Joint STARS was ahead of its time in developing programmable sensors. The use of open architecture, design flexibility, and COTS technology became a model for other systems. From the very beginning Motorola utilized commercial components and existing military equipment to the degree that the military specifications would allow. As the system evolved, the use of commercially available components increased. This transformation accelerated during the 1990s with the changes in the acquisition system under Secretary of Defense William Perry. In this sense, prior to DoD 5000, the Joint STARS program was a pioneer of many of its principles.

With reduction in non-critical military specifications and the emphasis on the use of commercial technology, in order to solve the problems of reliability and survivability, environmentally sealed enclosures were used with commercial cards in ruggedized chassis. Other innovative engineering solutions were implemented by Motorola in order to meet the system's performance objectives while maximizing the use of commercial components and computer hardware. Manny Mora of Motorola observed that the new emphasis on utilizing COTS technology allowed for greater opportunity for innovation on the part of the contractor, while significantly reducing cost and schedule (Manuel Mora, personal communication, March 19, 2002).

LESSON 8: ACHIEVING EFFECTIVE ARMY/USAF COORDINATION AND COOPERATION

Under DoD 5000 one of the major objectives in strategic planning is the identification of threats, which result in the opportunity for the development of joint capabilities. This predictably results in the reduction of duplication and cost effectiveness in systems development and deployment. Historically, the Army and Air Force have experienced difficulty in mastering cooperation, except in times of war. The Joint STARS program was a clear exception. While the program did not start out with strong cooperation, this changed in time due to several factors. In this sense, Joint STARS again pioneered one of the basic tenets of DoD 5000.

During the initial stages of the Joint STARS program there were significant disagreements between the Army and Air Force project offices as the system specifications were being determined. Bill Kenneally observed that the Army was initially somewhat of an unwilling partner. The Army had wanted its own GMTI program but understood that the options were either a joint program or no program at all. Prior to the finalization of the system specifications significant compromises had to be made. However, within several years as full scale engineering development proceeded, a spirit of cooperation and effective coordination developed.

Creating effective cooperation between two organizations cannot be accomplished without leadership that is emphasizing cooperation and leading by example.

Creating effective cooperation between two organizations cannot be accomplished without leadership that is emphasizing cooperation and leading by example. Charles Fowler observed that credit must be given to General James Stansberry, the commanding general at the USAF Electronics Systems Center, his successor, General Melvin Chubb, and Brigadier General Ed Franklin, the first Joint STARS project manager for the Air Force side of the program following the award of contracts. Since the Air Force was to be the lead on the system, Generals Stansberry, Chubb, and Franklin understood what it would take to achieve the necessary level of cooperation. To create an environment of cooperation, each concern of the Army's GSM project office was given a high level of priority and consideration. Each critical decision included participation from the Army Joint STARS GSM project office. In addition, the Army project office was kept informed of every important issue. On the Army side, the cancellation of the SOTAS program had been a devastating event. The Army needed a GMTI system, and the motivation was quite strong to make the Joint STARS program a success in the wake of the SOTAS failure.

As the research literature on cross-functional and cross-organizational integration has demonstrated, cooperation is a necessary but not sufficient condition for high levels of performance. What is also needed is the implementation of the proper modes of coordination among organizations. To accomplish this, the Army and Air Force project offices, Motorola, Grumman, Norden, and MITRE created collocated liaison positions to structurally facilitate and expedite coordination. This mode of coordination was utilized in conjunction with the usual means of coordination through joint meetings, transfer of documents, and direct communication. To illustrate, the Army and Air Force counterparts in the project offices would coordinate with one another and with their counterparts at Motorola for the Army GSM, and Grumman, MITRE, and Norden for the Air Force E8 and radar. MITRE would have its systems integration contract

personnel at Hanscom AFB, with liaison personnel collocated at Ft. Monmouth. Motorola actually had liaison personnel collocated with Grumman at the Melbourne facility.

In addition to the use of collocated liaison personnel the coordination between the Joint STARS GSM project office and Motorola was facilitated by properly designed integrated product teams (IPTs). Allan Tarbell observed that the teams not only included contractor and GSM project office personnel, but also technical specialists from the CECOM labs when needed. The use of collocated liaisons and IPTs with appropriate staffing facilitated timely disclosure of problems. One of the key characteristics that seemed to differentiate this successful use of IPTs from those that have failed was staffing. This means team composition with the right set of experts from the government and the contractor, with the proper level of decision authority. From all indications this approach worked effectively.

CONCLUSION

As operational testing, technology insertion, and other preplanned product improvements have continued on the Air Force side of the program, the Army has proceeded with its development of the GSM's successor, the Common Ground Station (CGS). The CGS leverages the GSM's open architecture and incorporates secondary imagery dissemination and other sensor data from multiple sources including unmanned aerial vehicles, providing tactical commanders with a more comprehensive view of the battlefield. The CGS represents a major step forward in battlefield surveillance for tactical commanders. The Common Ground Station also represents one of the cornerstones of DoD 5000: interoperability among multiple systems.

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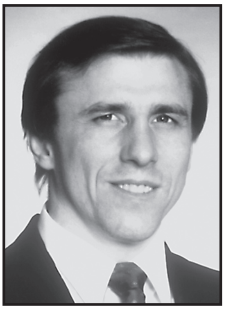

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